MANETs ON-DEMAND ROUTING PROTOCOLS IN CONTEXT OF ENERGY CONSUMPTION

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ABSTRACT: *Mobile ad hoc networks (MANETs) are resource constraint i.e. limited computational, communication and battery power, networks. On-demand routing protocols are widely used in these easy to deploy networks. Along with network performance evaluation, this paper used an energy consumption model [1] to analyze the energy that was consumed under three well-known on-demand routing protocols. Energy efficient solutions are desired in MANETs to maximize the life and performance of whole network. Our study revealed that DSR is not suitable in a highly mobile network. Although AODV routing protocol throughout maintained a moderate performance but consumed comparably higher amount of energy in routing overhead. AOMDV performed best among all the routing protocols. AOMDV has an edge to discover multiple routes in a single route discovery and a good choice for highly mobile networks. This study could be a valuable resource for those researchers that are engaged to propose energy efficient routing protocols.*

Keywords: *AODV Routing Protocol, Energy Consumption Model, Metrics, Network Simulator-2.*

INTRODUCTION

Mobile Ad Hoc Networks (MANETs) are infrastructure less, easy to deploy and mobility enabled wireless networks (depicted in figure.1). Such networks are very suitable to a situation where a network need to be deployed in a short time and with less professional expertise. The idea behind these networks was to facilitate the participants during emergency situations, inside military battle fields and natural disasters. Each participating node is responsible to help other nodes by carry out the network operations, side by side with other nodes. In this way a participating node is liable to spare its effort and perform the tasks for other network nodes. Apart from these attributes, there exists a tradeoff in these networks. The participating nodes are resource constraint i.e. limited computational power, limited storage, limited battery power etc. To acquire route and thus forward the packets, like in other networks, a routing protocol is used in MANETs. To ensure the delivery of one data packet, each ad hoc network routing protocol i.e. AODV [5], AOMDV [6] and DSR [7] generates different amount of routing packets. This additional burden to a network is known as routing overhead. It is widely perceived that the wireless interface of a typical participating mobile node would consume 18% of total battery power. A better and balanced approach between the cost of computation and communication would result in an energy efficient approach. Our paper considered Lucent WaveLAN network interface card [1] and provided the results of energy consumed by these three on-demand routing protocols.

Wireless networks especially Mobile Ad Hoc Networks (MANETs) are very famous due to its portability and mobility feature. But these features add more complexity to routing protocol behavior and thus increase their energy consumption. Under the scope of this paper, the on-demand routing protocols, which would discover a route whenever it is required, are studied. Due to mobility feature, there would be an increased frequency to discover a valid route to send the data packets. An interesting fact is that, the energy efficiency approach could not be designed for infrastructure networks because the traffic would definitely pass through certain base stations. Unlike infrastructure networks, MANETs can adopt an energy efficient approach during route discovery and other routing operations. This study could be helpful to evaluate on-demand routing protocols in terms of energy consumption. With the help of this analysis, researchers could further propose the energy efficient up gradation in the existing routing protocols.

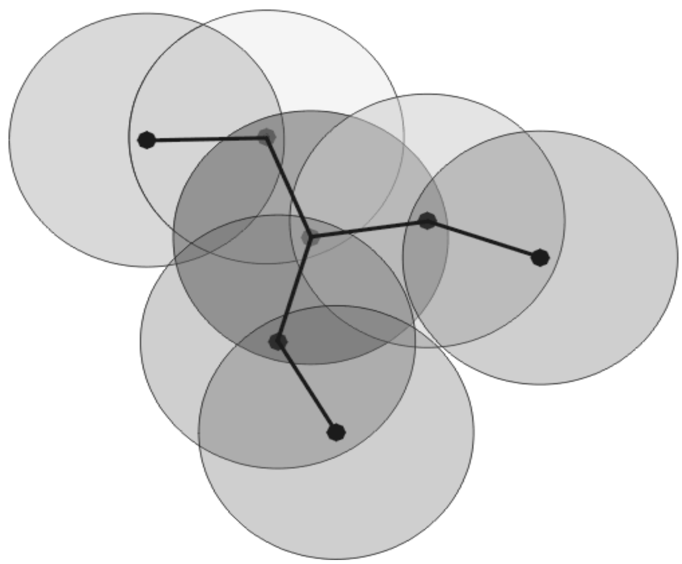

Fig. 1: An Ad Hoc Network Transmission Range.

This paper is organized as follows. Section II gives an overview of the energy consumption model and constants for 2.4GHz DSSS Lucent IEEE 802.11 WaveLAN Interface Card [1]. Section III provides details of on-demand routing protocols which are studied in context of energy consumption. Section IV and V contains simulation results and conclusion with future work, respectively.

ENERGY CONSUMPTION MODEL

Along with other performance evaluation factors of a network, the energy consumed by a network is considered an important factor. This paper would discuss the energy consumption aspect during the network traffic transmission and not the computational cost that each node pays to manipulate the traffic. There is a huge variety of network interface cards and a participating node is independent to use any kind of network interface.

Feeney et. al. [1], proposed an experimental measurement model based on the IEEE 802.11 standard, for energy consumed by each packet. Energy constant values of a well-known interface card "the 2.4GHz DSSS Lucent IEEE 802.11 WaveLAN Interface Card", are given in Table 1.

Table 1. Energy constants used in the simulation [1]

Parameters	Values
m_{send}	1.89 mW.s/byte
b_{send}	246 mW.s
m_{recv}	0.494 mW.s/byte
b_{recv}	56.1 mW.s
$m_{discard}$	-0.490 mW.s/byte
$b_{discard}$	97.2 mW.s
$m_{recv\_promiscuous}$	0.388 mW.s/byte
$b_{recv\_promiscuous}$	136 mW.s
$b_{sendctl}$	120 mW.s
$b_{recvctl}$	29.0 mW.s

By using this linear energy consumption model, we evaluated the MANET on-demand routing protocols. The energy consumption is further explained in following equations:

$$Energy\ Cost = m \times size + b \rightarrow (1)$$

Energy Cost: the energy consumed by an operation.
m: an incremental value associated for each operation.
b: fixed cost associated for each operation.
size: the packet size that is either sent or received.

We calculated the cost of all data packets that were sent in a network, using the following equation:

$$Energy\ Cost\ at\ Sender = b_{sendctl} + b_{recvctl} + m_{send} \times size + b_{send} + b_{recvctl} \rightarrow (2)$$

The receiving cost for all data packets that were received and the cost for routing packets that were received for each data packet are computed by using the equation 3:

$$Energy\ Cost\ at\ Receiver = b_{recvctl} + b_{sendctl} + m_{recv} \times size + b_{recv} + b_{sendctl} \rightarrow (3)$$

These equations include some fixed cost that is needed for MAC layer operations (RTS/CTS) and the incremental cost that represents the amount of data. Both the point-to-point and broadcast traffic transmission can be calculated by this model. Along with calculating the energy consumed by source and destination, this model can calculate the energy spent by non-destination nodes in a transmission range [2, 3]. Three new energy consumption metrics are further discussed in section IV.

ON-DEMAND ROUTING PROTOCOLS

We considered the three well-known on-demand routing protocols:

-Ad Hoc On-Demand Distance Vector (AODV): AODV [5] is an on-demand (reactive) single-path, hop-to-hop routing standard protocol. The route discovery starts with a broadcast RREQ (route request) that travels to almost every node but forwarded by intermediate node, only once. Each RREQ is differentiated with a unique identification number and the requested destination. An intermediate node would just forward only once, each RREQ that it receives. An entry for the rebroadcasting of RREQ is stored by the intermediate to establish a reverse path if this node would be selected as a part of discovered route. The later same RREQ is discarded by the intermediate to ensure a finite broadcast. RREP (route reply) is sent back to the source by the destination and in some cases from an intermediate that claims to have a fresh enough route. The RREP then traverse back to the source through all the intermediate nodes that were part of the RREQ route. Unlike RREQ, the RREP is sent back to source with a point-to-point transmission.

By using RERR (route error), AODV provides the route maintenance feature. A RERR is sent to all those nodes that could be affected by a route failure caused due to mobility or link failure etc. The destination only responds to the first RREQ that reaches it and the later RREQ are discarded by the destination. This ensures that only single-path that is shortest, would be discovered.

-Ad Hoc On-Demand Multipath Distance Vector (AOMDV): AOMDV [6], is an on-demand (reactive), multi-path, hop-to-hop routing standard that mostly inherits AODV behaviors. Similar to AODV - RREQ, RREP and RERR are used to find the route, get the route and report the route failure, respectively. Like AODV, all the RREQs are treated in the same way as AODV by an intermediate node. Which mean that every intermediate node would only forward few received RREQs that fulfill certain criteria and thus remaining requests would be discarded. There are two criteria i) node disjoint and ii) link disjoint. AOMDV could be configured to discover the link (no common link between any given pair of nodes) or node (in addition to link disjoint, common intermediate nodes are also excluded between any given pair of nodes) disjoints paths [9].

Disjoint paths as an alternate route, are a good choice than overlapping alternate paths because the probability of their interrelated and concurrent failure is smaller. This property can be helpful to achieve load balancing and shared energy consumption. We only considered the default criteria of AOMDV – disjoint path.

-Dynamic Source Routing (DSR): DSR [7] is also an on-demand (reactive), single-path but source routing based standard protocol. Similar to both above protocols, the route discovery and maintenance is composed of RREQ, RREP and RERR. Unlike previously mentioned protocols, whole route is accumulated with each packet that is sent and forwarded under this protocol. Such additional payload works fine while low mobility but causes performance degradation as soon as the mobility becomes high. Although DSR is known to be a better approach than proactive routing protocols but the routing overhead is increased if the length of learned route is long.

The RREQ is broadcast and same RREQ would only once forwarded by an intermediate node. The RREP is uni-casted by the destination or in case of enabled promiscuous mode, by the intermediate node that claims to have a fresh enough route for the requested destination. A RERR would be generated after few unsuccessful attempts between two nodes. The route error would then be sent to all affected nodes. A broken link could not be locally repaired and the end to end delay is comparatively higher than AODV and AOMDV.

These three on-demand routing protocols are evaluated both in terms of performance and energy consumption.

SIMULATION AND ANALYSIS

The simulations are performed by using Network Simulator-2 [8]. Results are compiled under four performance metrics [4, 9] i.e. Packet Delivery Ratio, End-to-End Delay, Normalized Routing Overhead, Packet Dropping Rate and three new energy consumption metrics i.e. Energy Consumed at Source Nodes, Energy Consumed at Destination Nodes, Energy Consumed by Routing (packets received) Overhead. Table 2 explains the network parameters that were used in our simulation. All other parameters are static and only the mobility was varied from 0(high) to 500 (low).

Parameters	Values
Simulation Time	900 Seconds
Space	1000 x 1000
Number of Nodes	50
Transmit Power	250 m
Connections	20
Traffic Type	CBR
Nodes Speed	20 m/s
Packet Generation Rate	4 packets/s
Packet Size	512 kb
MAC Protocol	802.11
Mobility Model	Random Waypoint
Mobility	0, 100, 200, 300, 400 & 500

Table 2. Simulation Parameters

Further explanation for three energy consumption metrics is given below:

- Energy Consumed at Source Nodes: Calculated the total energy consumed by all source nodes to send the data packets during the simulation time of 900 seconds.
- Energy Consumed at Destination Nodes: Calculated the total energy consumed by all the destination nodes to receive the data packets during the simulation time of 900 seconds.
- Energy Consumed by the Routing Overhead: Calculated an average energy that was consumed to receive the routing packets needed to deliver a data packet during the simulation time of 900 seconds.

The packet delivery ratio (PDR) is illustrated in figure. 2. AOMDV and AODV maintained throughout same delivery ratio but the DSR gave poor delivery ratio as soon as the mobility becomes high. Among both AODV and AOMDV, AOMDV achieved better results, due to the fact that it learns multiple routes in single route discovery. If a primary route is invalidated, the secondary route would right away be used and the same delivery ratio could be maintained without any delay that is required for another route discovery.

End-to-End delay is illustrated in figure. 3. It is the average delay that each packet faces to discover the route as well as time consumed for arrival to destination. Both AODV and AOMDV maintained somewhat same end-to-end delay but the DSR took way too long for a successful delivery of each data packet. Among AODV and AOMDV, AODV due to its lightweight and single route discovery, spent lesser time for each data packet that is received to destination. An improved end-to-end delay would achieve better overall network performance.

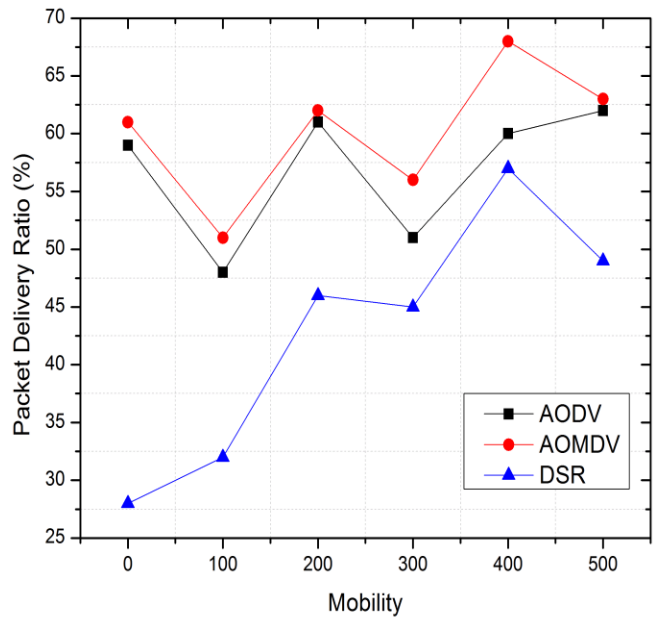

Fig. 2: Packet Delivery Ratio.

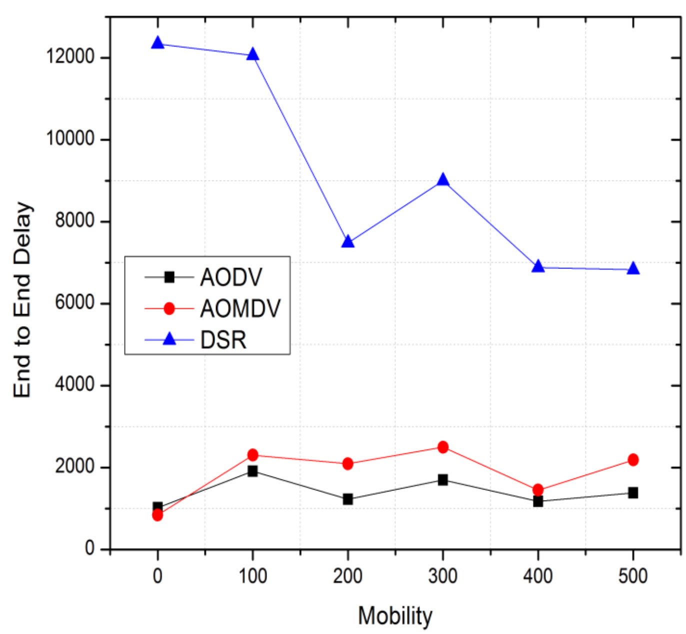

Fig. 3: End to End Delay.

Normalized routing overhead is illustrated in figure. 4. It is the average number of routing packets that need to be delivered for each data packet. AOMDV achieved the lowest among all the routing protocols that are studied in this paper. AOMDV can discover more than one route in a single route discovery. AODV achieved better and same routing overhead throughout the simulations. The routing overhead starts increasing as soon as the mobility becomes higher in DSR. DSR is considered inefficient in a high mobility environment [7].

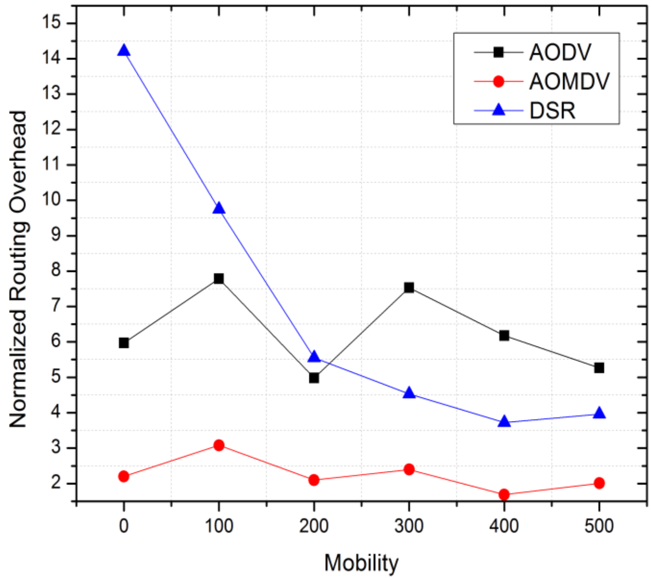

Fig. 4: Normalized Routing Overhead.

Packet dropping rate is illustrated in figure. 5. It shows the data packets that were been dropped due to link failure, no route to destination, mobility etc. AODV dropped highest data packets and AOMDV was second highest. DSR remained least data dropping routing protocol. But we should keep in mind that the delivery ratio of DSR is much lower than both AODV and AOMDV, in our simulations. It is the fact that the probability of data packet dropping is directly proportional to the data deliver that a routing protocol achieves.

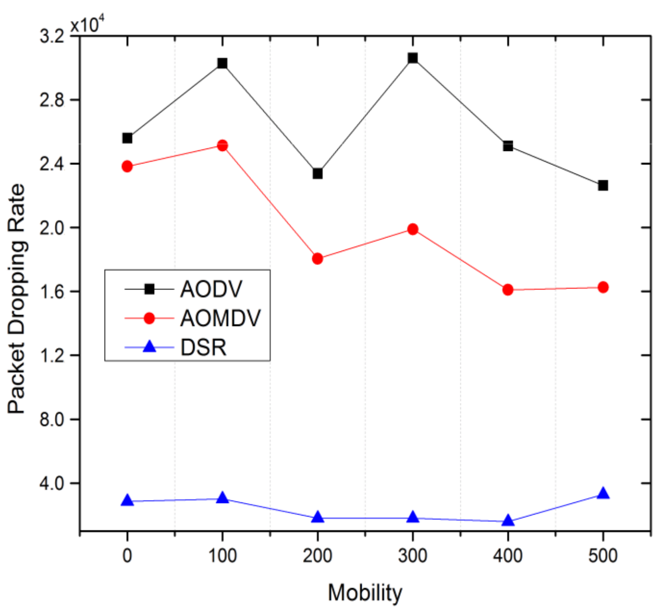

Fig. 5: Packet Dropping Rate.

The energy that was used to send all the data packets during the simulations is illustrated in figure. 6. The end-to-end delay by AODV is lowest among all the routing protocols that we studied. This is the reason that the energy spent in AODV to send data packet is higher than other routing protocols. Second highest energy was consumed by AOMDV but in DSR the energy consumption had a hike while moderate mobility and it reduced when the mobility is high.

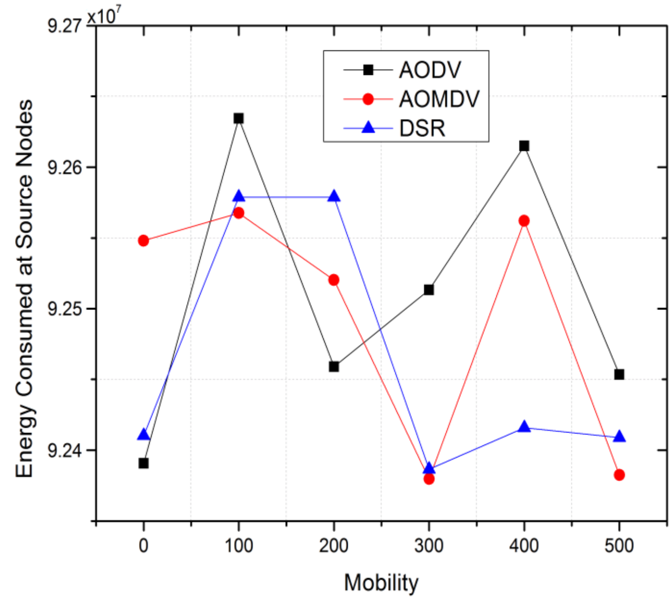

Fig. 6: Energy Consumed at Source while Sending all the Data Packets.

Figure. 7. shows the energy consumed by all nodes while receiving all the data packets. These results have same variation as in packet delivery ratio (PDR). All nodes while using AODV and AOMDV, spent more energy than DSR routing protocol. AODV and AOMDV consumed same amount of energy but the amount of energy declined in DSR as soon as the mobility became high.

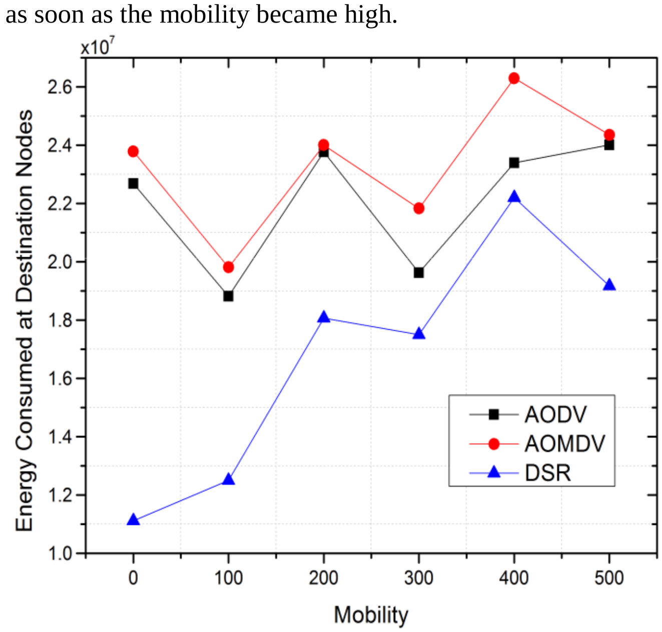

Fig. 7: Energy Consumed at Destination while Receiving all the Data Packets.

An average energy that was consumed by the routing packets to deliver each data packet is illustrated in figure. 8. The routing overhead is associated with the increase in mobility. There was an increase in routing overhead and thus the energy consumed by all the routing protocols that were studied, as soon as the mobility became high. AODV consumed noticeable higher amount of energy, AOMDV remained second highest and DSR remained lowest in this scenario. We should keep in mind that the delivery ratio for DSR was comparably lower and decreased as soon as the mobility increased. Along with this fact, the energy consumed by DSR was increased with the increase in mobility.

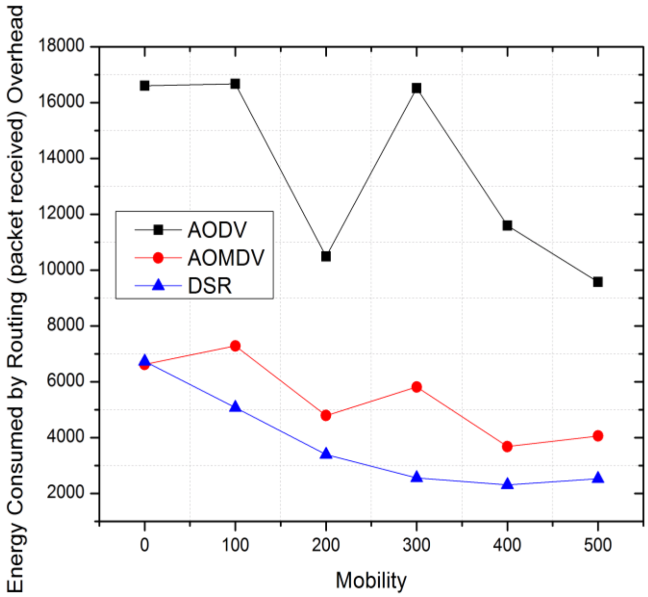

Fig. 8: Energy Consumed by Routing Packets that were Received, to Send a Single Data Packet.

CONCLUSION

Our simulations helped us to find following main facts:

- ✓ Results show that the performance of DSR degrades as the mobility increased. Network performance criteria i.e. delivery ratio, end-to-end delay, routing overhead and the comparatively higher energy consumption, proved that DSR is a wrong choice for high mobility networks.
- ✓ AODV maintained a moderate network performance and lower energy consumption. Although it is considered a lightweight protocol but the energy consumed by the routing overhead was considerably higher, in our simulations.
- ✓ AOMDV performed well in terms of network performance and energy consumption. The advantage that it could learn more than one routes in single route discovery, gives an edge to this routing protocol.

This simulative study could help researchers to learn the energy consumption aspects of on-demand routing protocol. In this way, one could propose an energy efficient [10-12] routing protocol.

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